

The background of the slide is a composite image. The top half shows a bright blue sky with wispy white clouds. The bottom half shows a calm body of water, likely a lake, with a rocky shoreline in the foreground. On the left side of the bottom half, there is a patch of tall, dry, yellowish-brown grass. The overall scene is peaceful and natural.

MODEL INTEGRATION FOR ASSESSING FUTURE HYDROCLIMATE IMPACTS ON WATER RESOURCES, AGRICULTURAL ECONOMIC SUSTAINABILITY AND ENVIRONMENTAL QUALITY

**Nigel W.T. Quinn,
Levi D. Brekke Kathy L. Bashford, Norman L. Miller,
Hugo Hildago, Pallavi Raju, John A. Dracup**

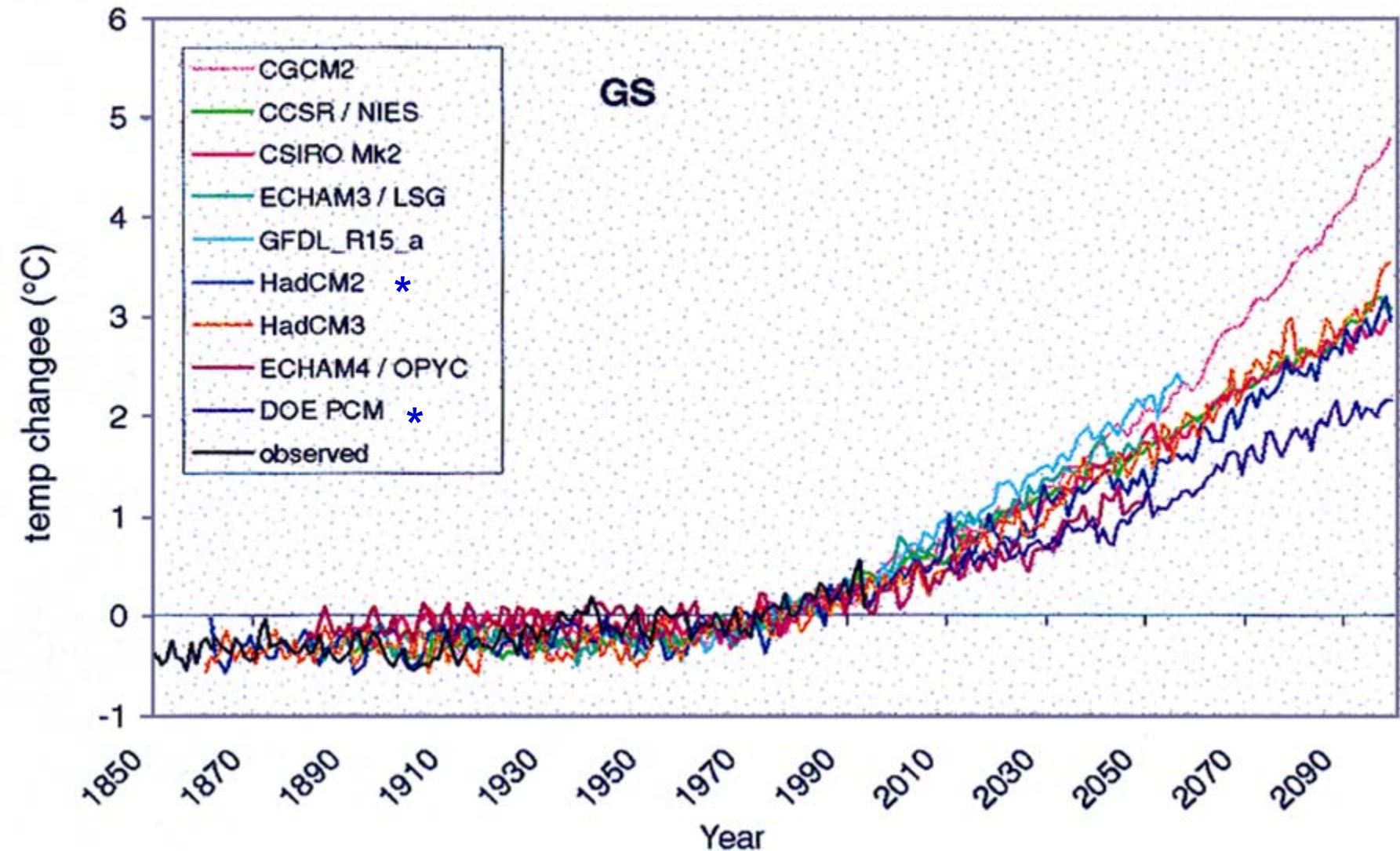
**Berkeley National Laboratory
University of California, Berkeley**

**iEMSS 2002, Lugano Switzerland
June 25-28, 2002**

EVIDENCE OF CLIMATE CHANGE LAST CENTURY

- **Warming trend globally**
 - Increased sea surface temperatures
 - Retreat of mountain glaciers
- **Warming trend in California**
 - Long term decrease in proportion of streamflow occurring in Spring
 - Earlier initial snowmelt
 - Increased salinity in Bay-Delta estuary

IPCC TAR Projected 2100 Global Temperature Increase: 1.4°C to 5.8°C



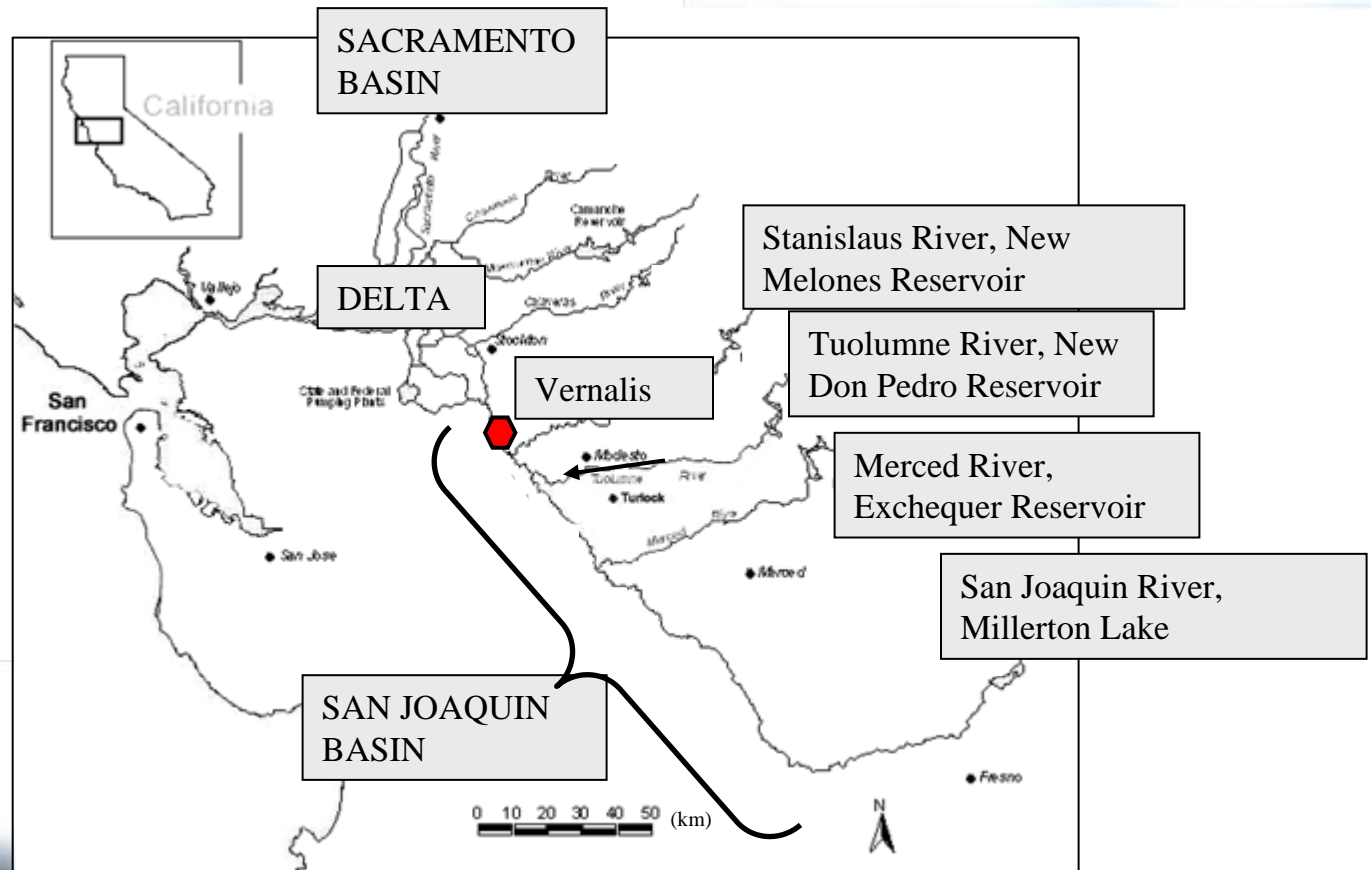
POTENTIAL IMPACTS

- **Warmer** winter storms
- **Earlier runoff** from the Sierra snow pack
- **Reduced summertime flow** in tributary streams
- The above conditions can:
 - **adversely affect** the **reliability** of water supply
 - can produce **extreme runoff** events that could overwhelm the water conveyance and distribution system within the watershed and lead to unusually high exports of salt, selenium and boron in the San Joaquin River
- High levels of salt and boron not only affect the **water quality** but also can significantly reduce crop yield, leading to **reduced agricultural income** and **regional socioeconomic impacts**

RESEARCH OBJECTIVES

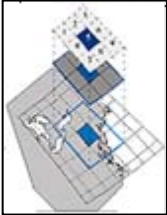
- **Acquire and develop** models to simulate resource response and sensitivity to climate change and climate variability
- **Link and integrate** models of water resources, water quality, economics and fishery resources within a data centered, GIS-based model support system
- **Simulate and assess** the vulnerability of these resources to a series of future climate change scenarios
- **Develop** strategies to help resource agencies adapt to future potential climate change and climate variability

PROJECT STUDY AREA: San Joaquin Basin



ASSESSING WATER RESOURCES AND ENVIRONMENTAL IMPACTS UNDER CLIMATE CHANGE IN ARID AREAS

- Downscaled global circulation models
- Terrestrial rainfall–runoff–temperature model
- Rule-based reservoir water allocation model
- Fish population and survival model
- Hydrodynamic river flow and water quality model
- Agricultural production, irrigation and drainage model
- Regional economic impacts model



MODEL SYSTEM DRIVER : CLIMATE-ALTERED HYDROLOGY

- Approach for developing Climate-Altered Hydrology:
 - Relate historical weather (basin-scale) to historical atmospheric circulation (regional-scale); construct a model based on this relationship.
 - Force the model using atmospheric circulation forecasts; get forecasts from GCM (General Circulation Model) output.

MODEL SYSTEM : CLIMATE DOWNSCALING MODEL



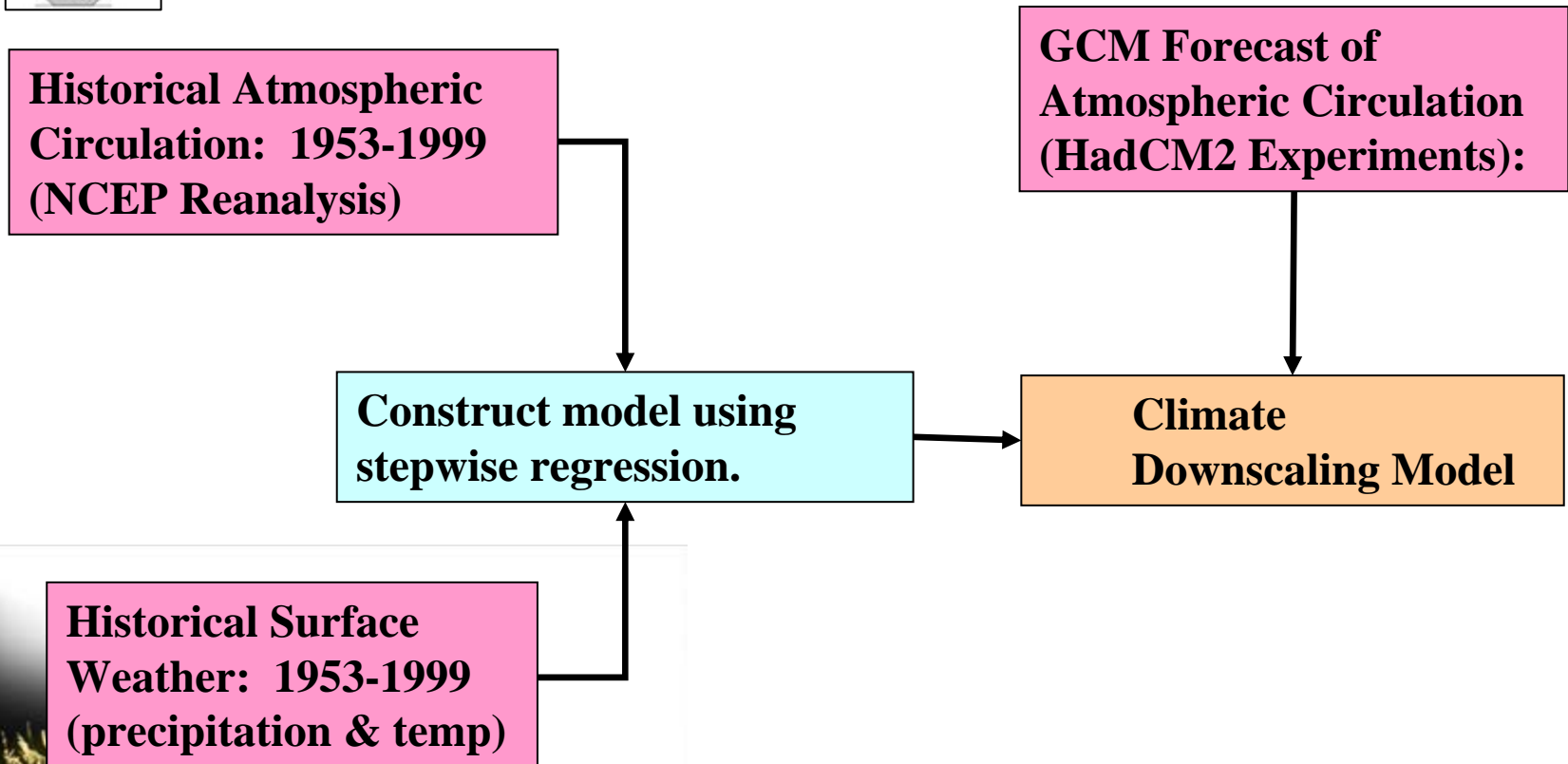
**Historical Atmospheric
Circulation: 1953-1999
(NCEP Reanalysis)**

**Construct model using
stepwise regression.**

**Historical Surface
Weather: 1953-1999
(precipitation & temp)**



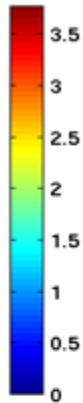
MODEL SYSTEM : CLIMATE DOWNSCALING



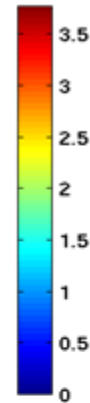
GCM-Simulated Temperature Change (absolute)

$T_{\text{projected}} - T_{\text{baseline}} (^{\circ}\text{C})$

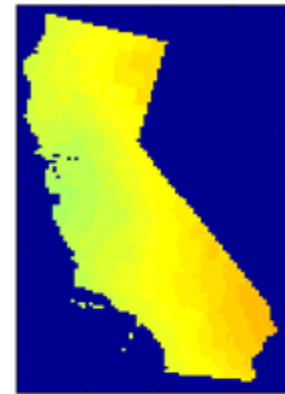
PCM, 2010–2039



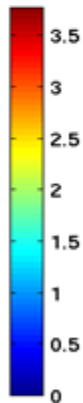
PCM, 2050–2079



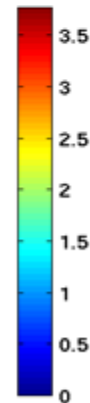
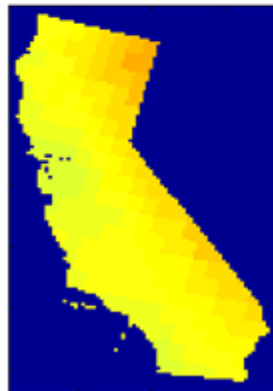
PCM, 2080–2099



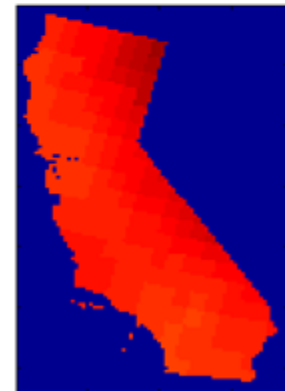
HCM, 2010–2039



HCM, 2050–2079



HCM, 2080–2099



GCM-Simulated Precipitation change (ratio)

$$P_{\text{projected}}/P_{\text{baseline}}$$

PCM, 2010–2039



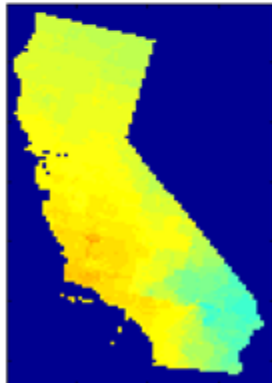
PCM, 2050–2079



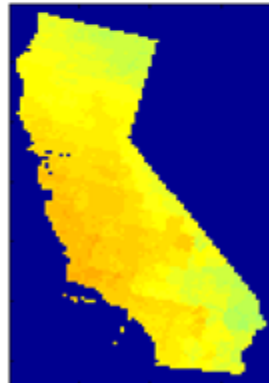
PCM, 2080–2099



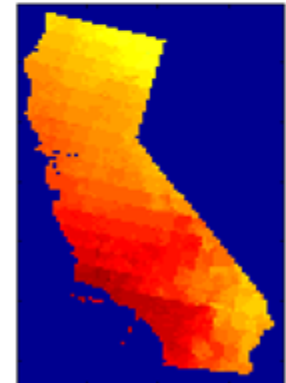
HCM, 2010–2039



HCM, 2050–2079



HCM, 2080–2099





MODEL SYSTEM : RAINFALL / RUNOFF

**Historical Atmospheric
Circulation: 1953-1999
(NCEP Reanalysis)**

**GCM Forecast of
Atmospheric Circulation
(HadCM2/PRM
Experiments):**

**Construct model using
stepwise regression**

**Historical Surface
Weather: 1953-1999**

**Climate
Downscaling Model**

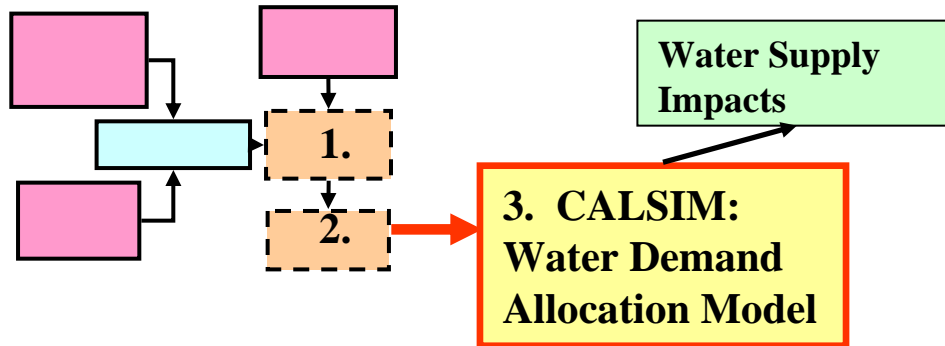
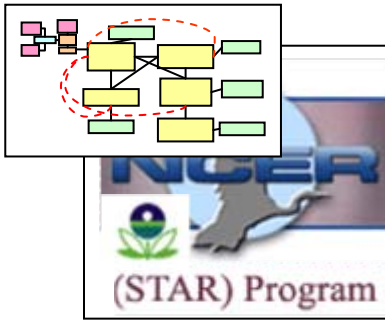
**Rainfall/Runoff Model
(PRISM)**

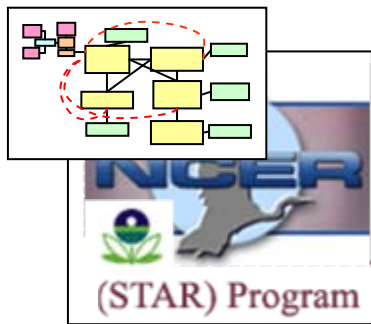


STREAMFLOW PERTUBATION FUNCTIONS

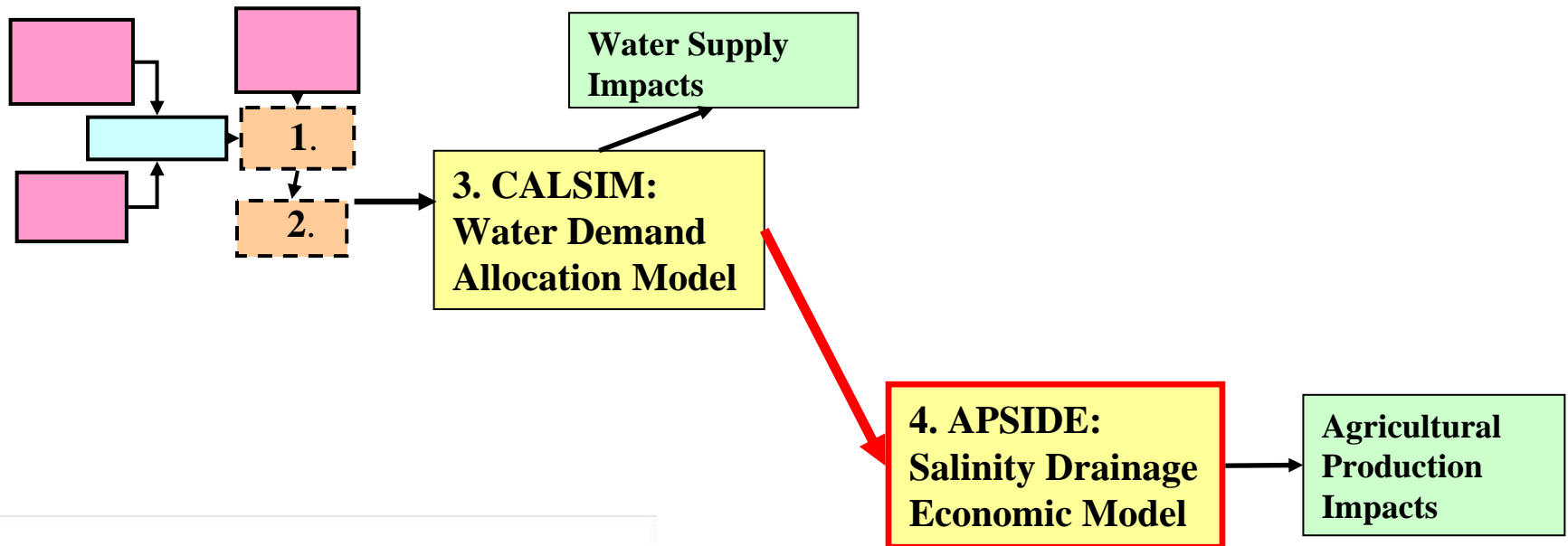
HadCM Streamflow ratios	2010- 2039	2050- 2079	2080- 2099
Oct - Mar	~2	~2	~5
Apr - Sept	~0.8	~0.8	~0.5
PCM Streamflow ratios	2010- 2039	2050- 2079	2080- 2099
Oct - Mar	~1	~1	~1
Apr - Sept	~0.5	~0.5	<0.5

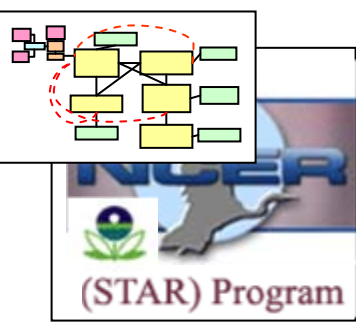
MODEL SYSTEM: WATER ALLOCATION / RESERVOIR OPERATION



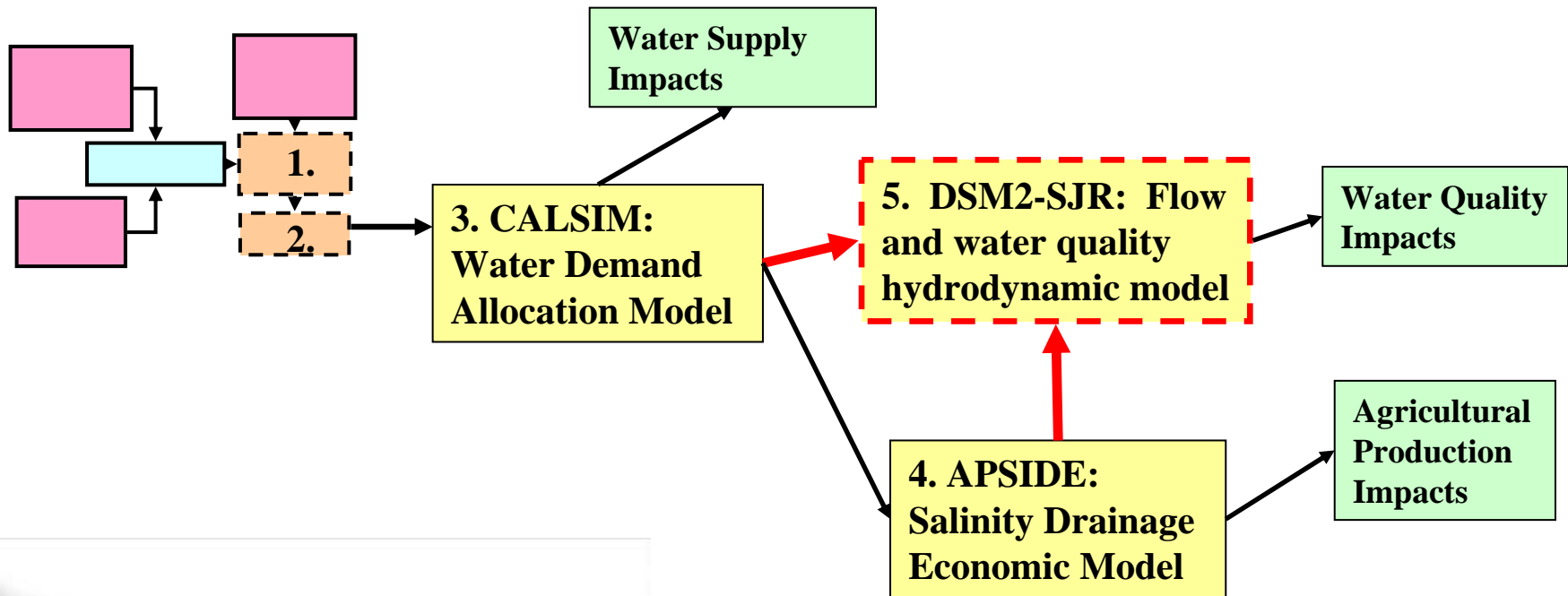


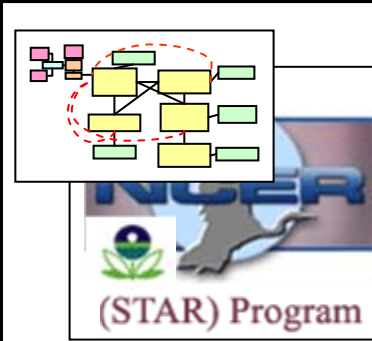
MODEL SYSTEM : AGRICULTURAL PRODUCTION / DRAINAGE WATER QUALITY





MODEL SYSTEM : RIVER FLOW AND WATER QUALITY





MODEL SYSTEM : RIVER FLOW AND WATER QUALITY

■ CALSIM

- Flexible operational model
- Optimized (linear programming) water allocation decisions
- Continuity equations

■ DSM-2-SJR

Hydrologic routing (HYDRO)

- Channel Geometries
- Hydraulic Characteristics (Manning's "n", slope, Cross Sections, etc)
- Flow equations (Continuity, Manning's, routing, etc)
- Water Quality (QUAL module)



LINKING CALSIM II WITH DSM2-SJR AND APSIDE

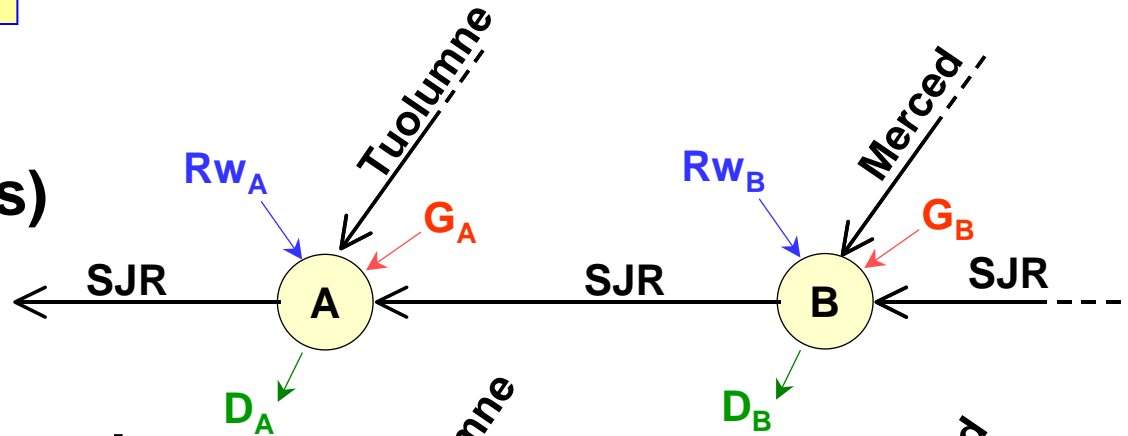
DSM2-SJR Inputs

G: Gains (CALSIM II)

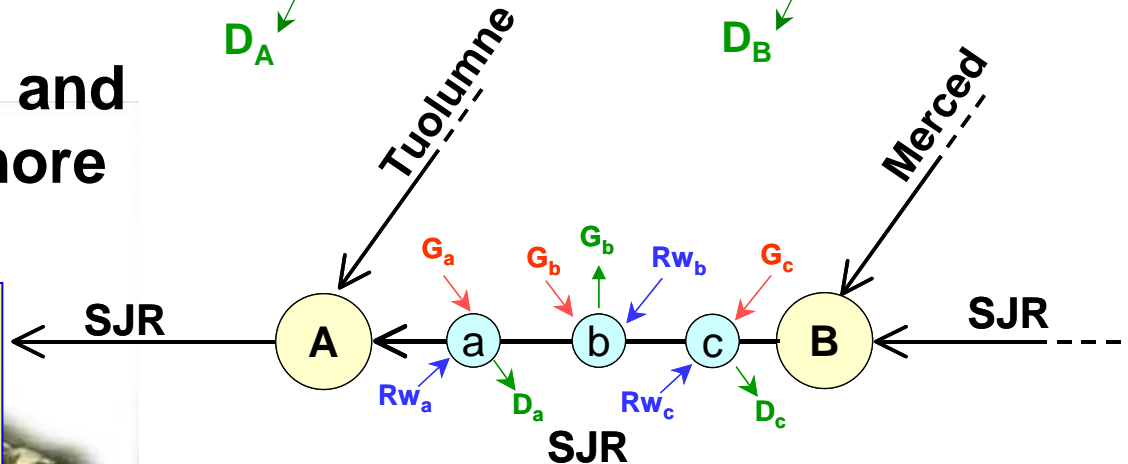
D: Deliveries (CALSIM II)

R: Returns (APSIDE)

**CALSIM II
(less nodes)**

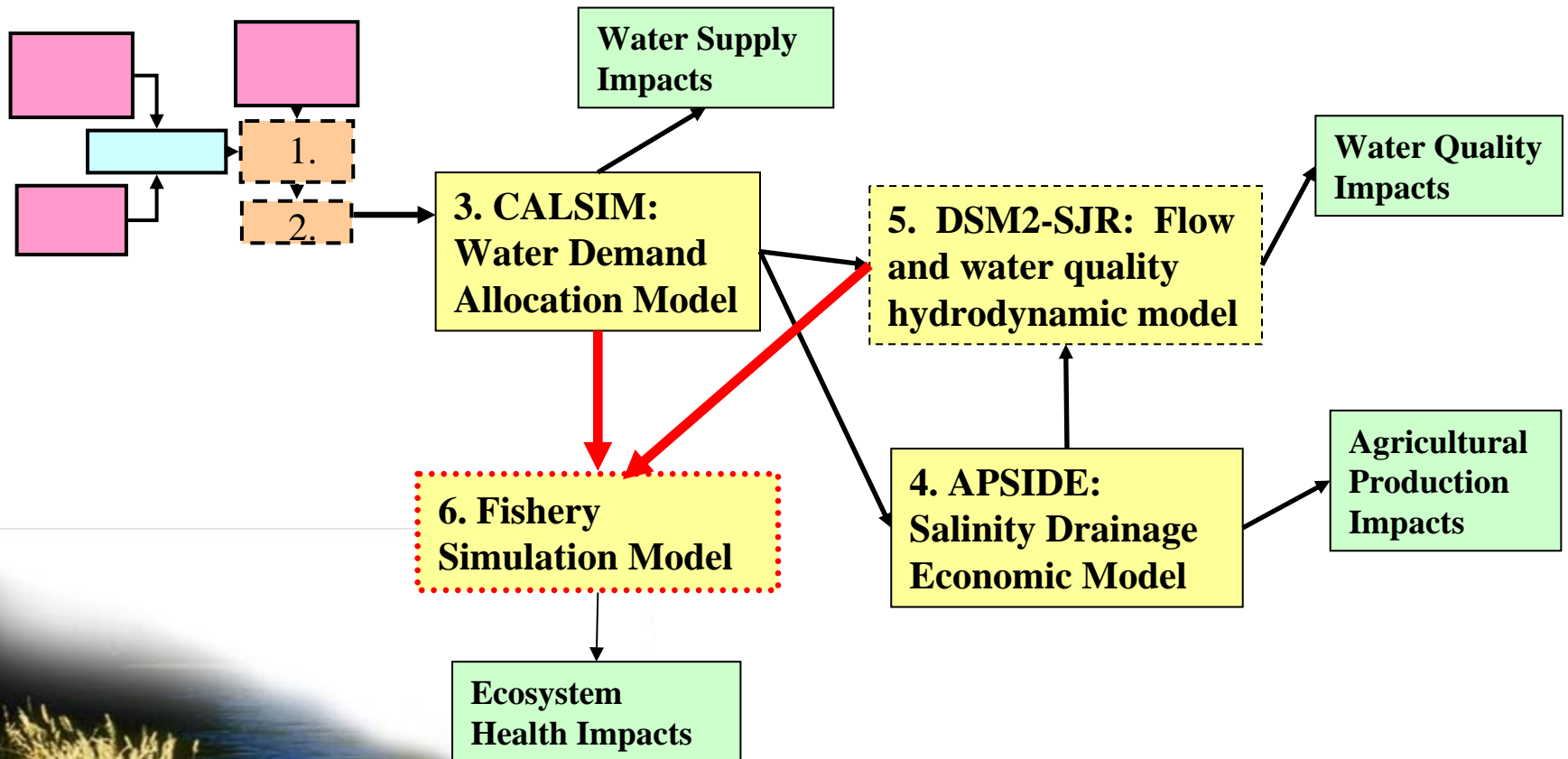
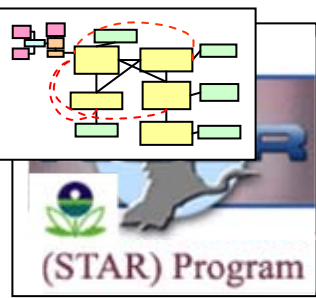


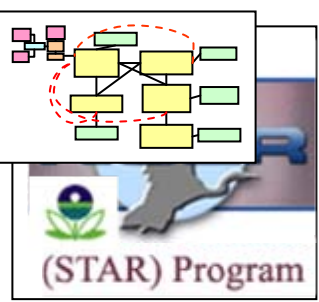
**DSM2-SJR and
APSIDE (more
nodes)**



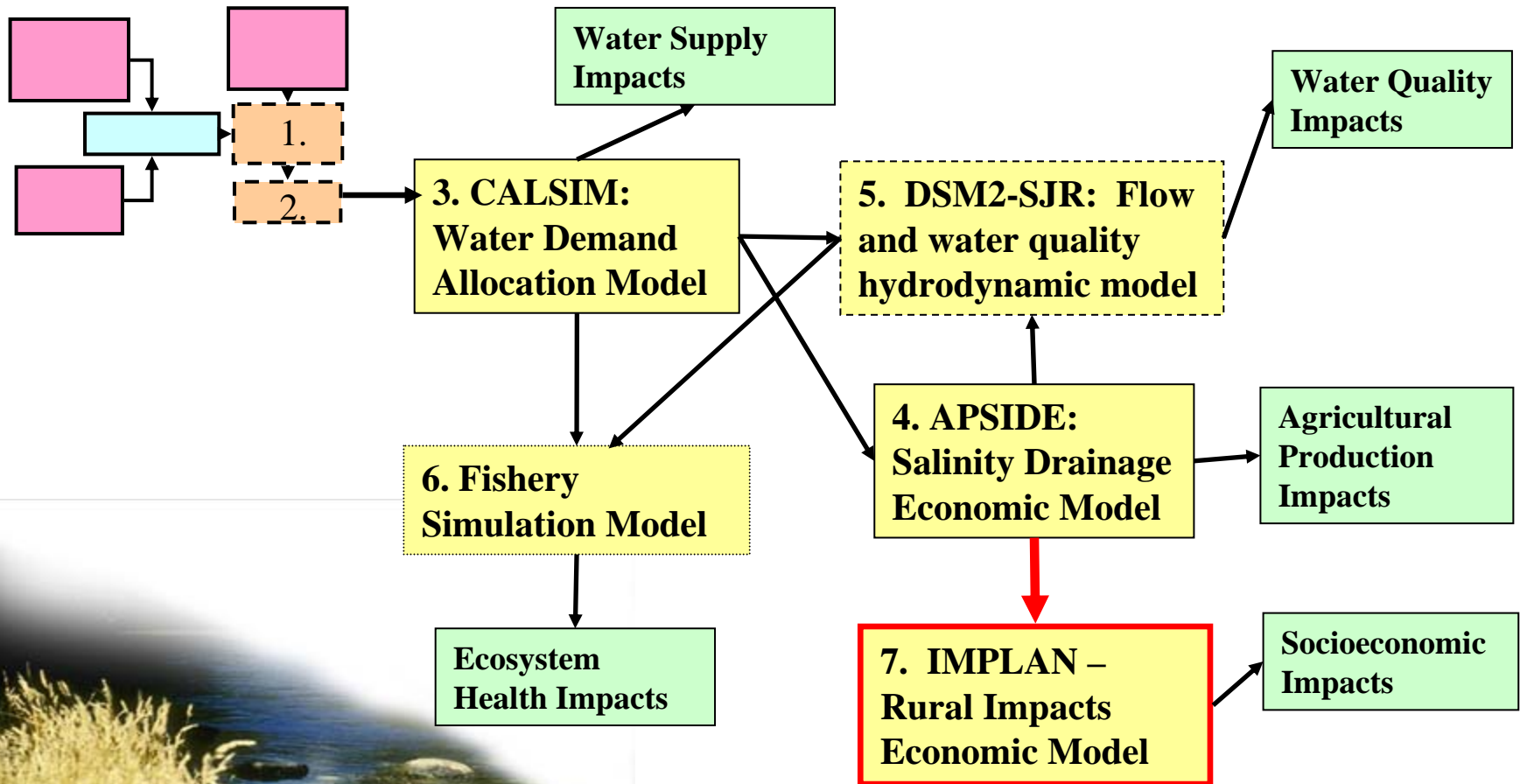
Difference in node
resolution requires data
disaggregation...

MODEL SYSTEM : FISHERY / ECOSYSTEM

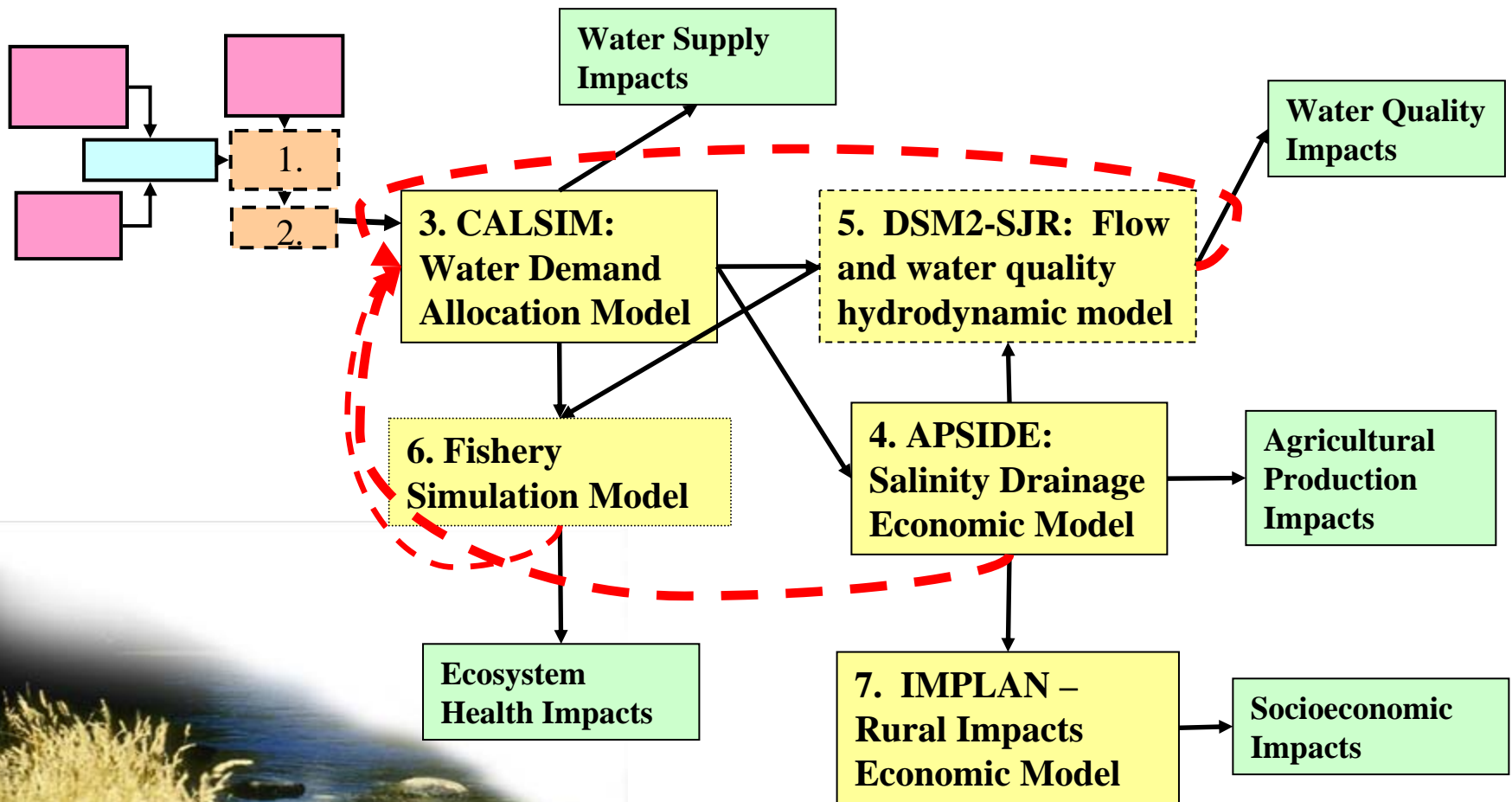
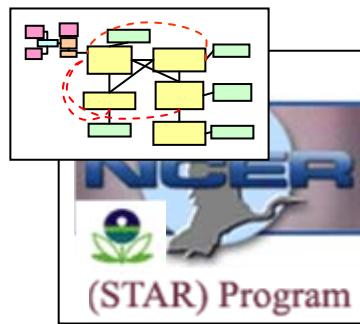




MODEL SYSTEM : SOCIOECONOMICS



MODEL SYSTEM : FEEDBACK LOOPS



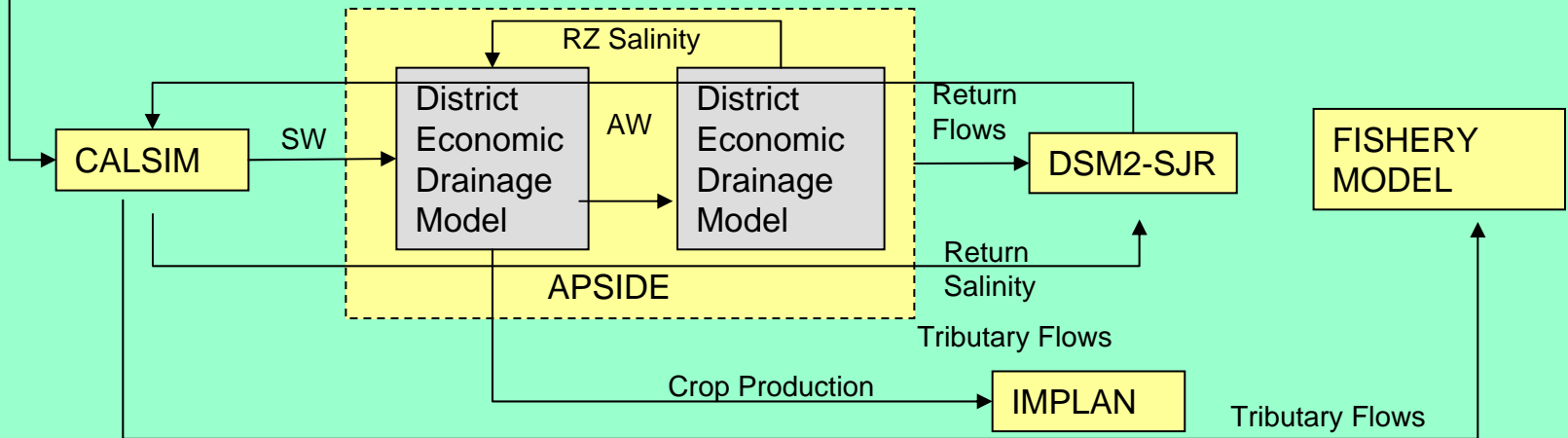
Hydrologic Scenario
relative to 1922-1995
observed hydrology:

(e.g., no change,
climate change)

Vernalis Salinity (feedback to water allocation)

Object User Interface software:

- organize models and data files
- GUI for geographic data visualization and tabular or graphical data access
- controls for model execution



Models:

CALSIM : reservoir operations & water allocation model for Sacramento-San Joaquin River Basin

APSIDE : San Joaquin River Basin agriculture production model

DSM2-SJR : San Joaquin River hydrodynamic model; developed in Delta Simulation Model 2 framework

IMPLAN : Economic Indicators model; county scale in San Joaquin Basin

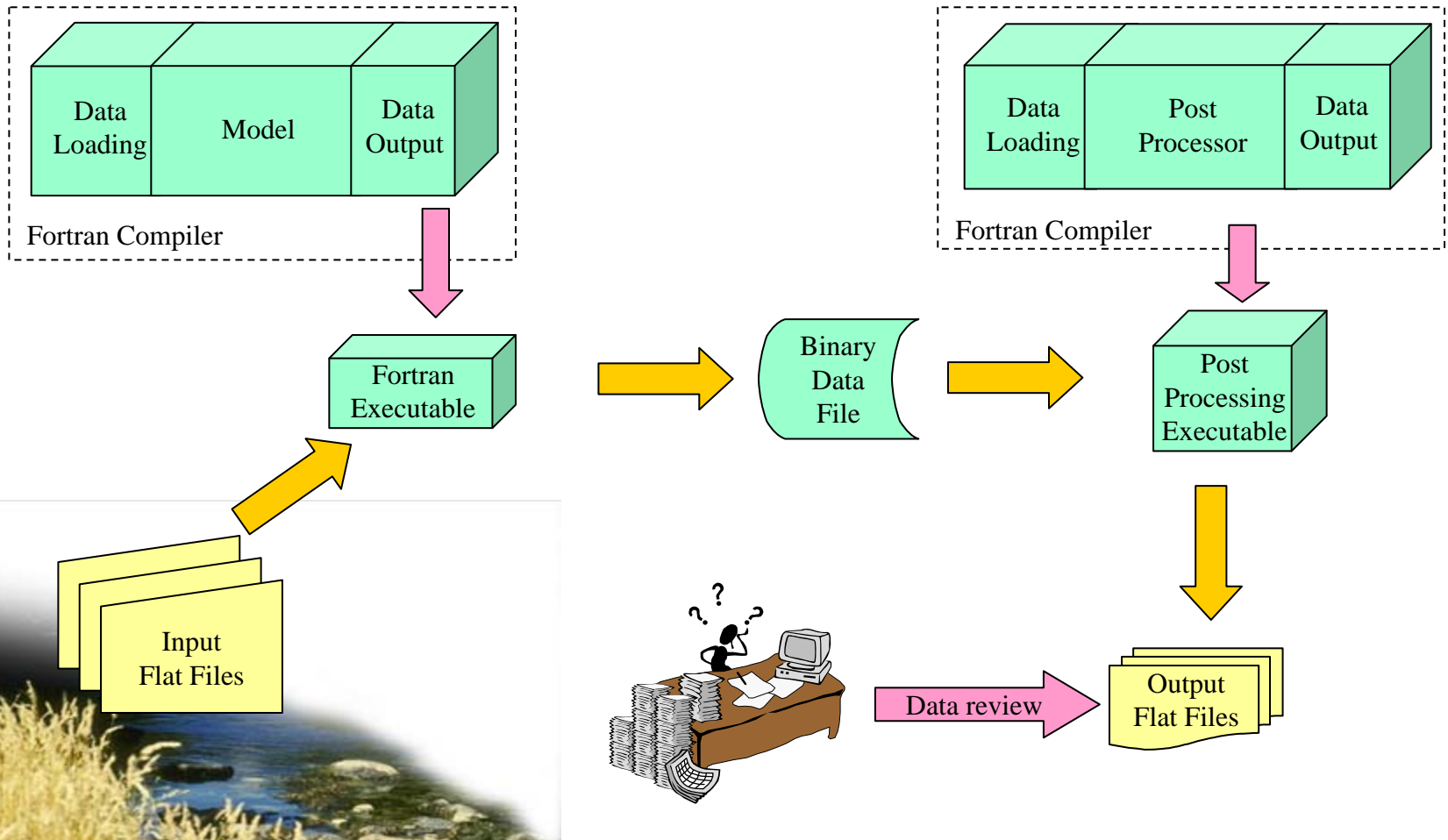
FISHERY MODEL : Stream temperature model; for fish habitat assessment

INTEGRATION FEATURES :

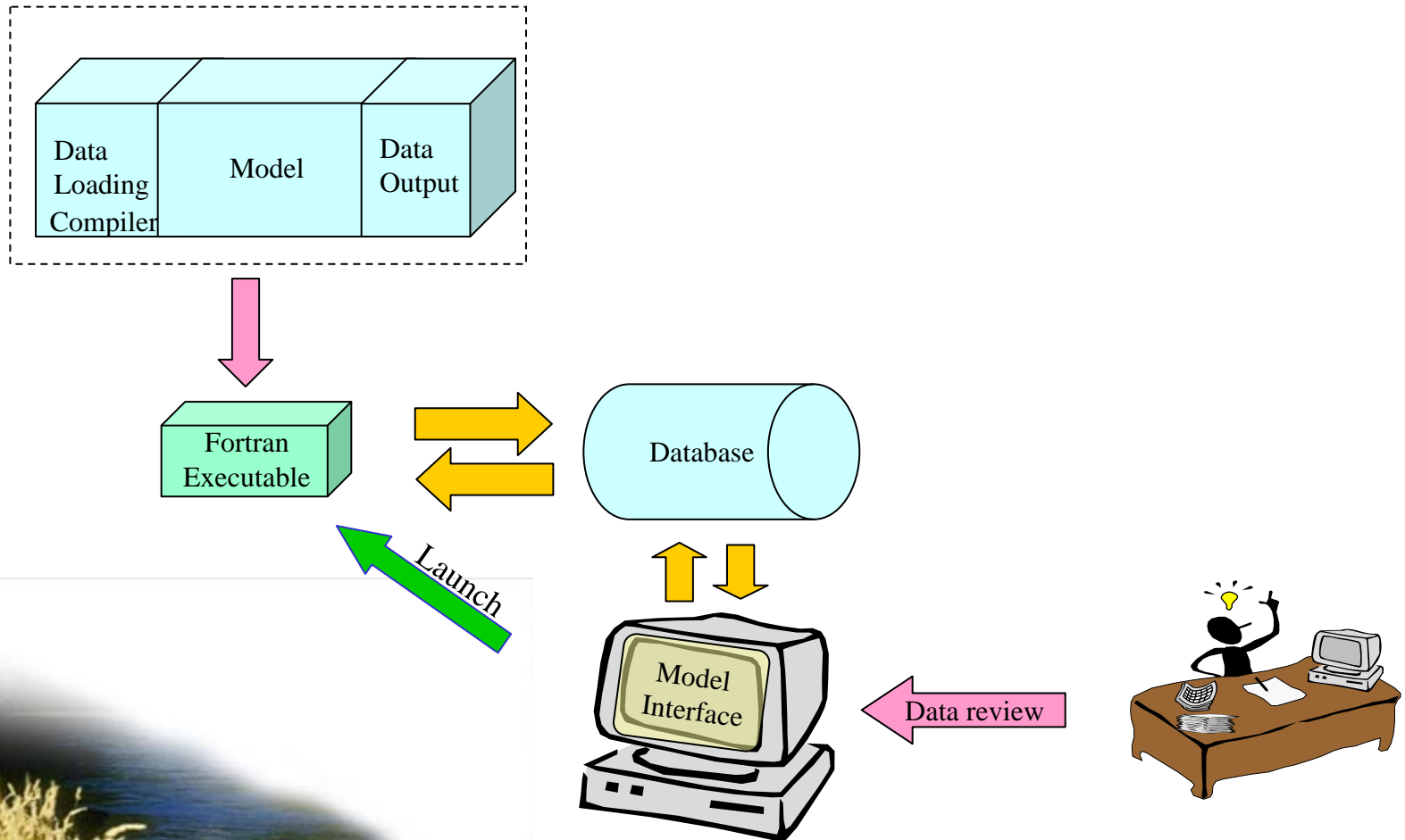
- Integrate models into a model system
- database-centered
- model-scale
- platform independent
- GIS-based interface for models and modeling



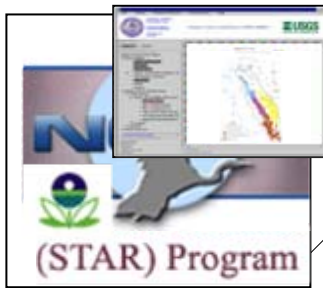
CURRENT MODEL DATA MANAGEMENT PARADIGM



PROJECT MODELING PARADIGM



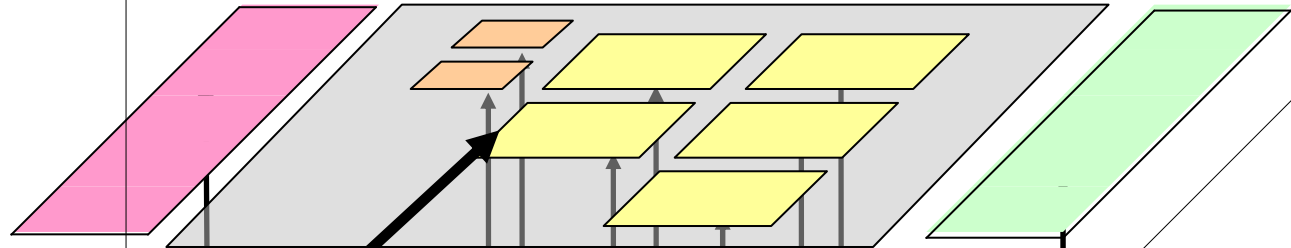
MODEL LINKAGE



Data Sources

Model system

GIS-based
analysis toolbox



1) Subdivide model system into individual model objects.

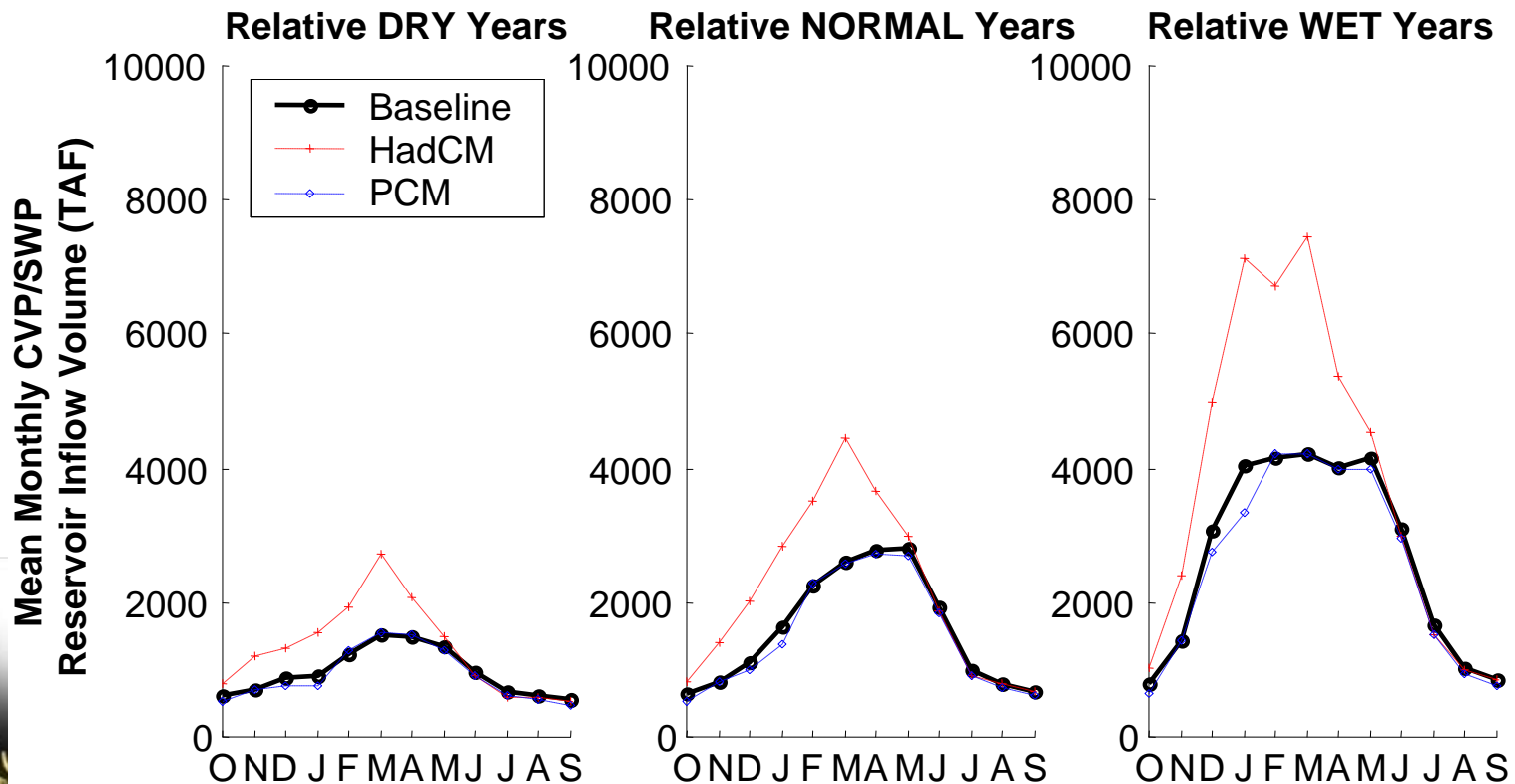
Data Storage System (DSS)

Model
integration
system

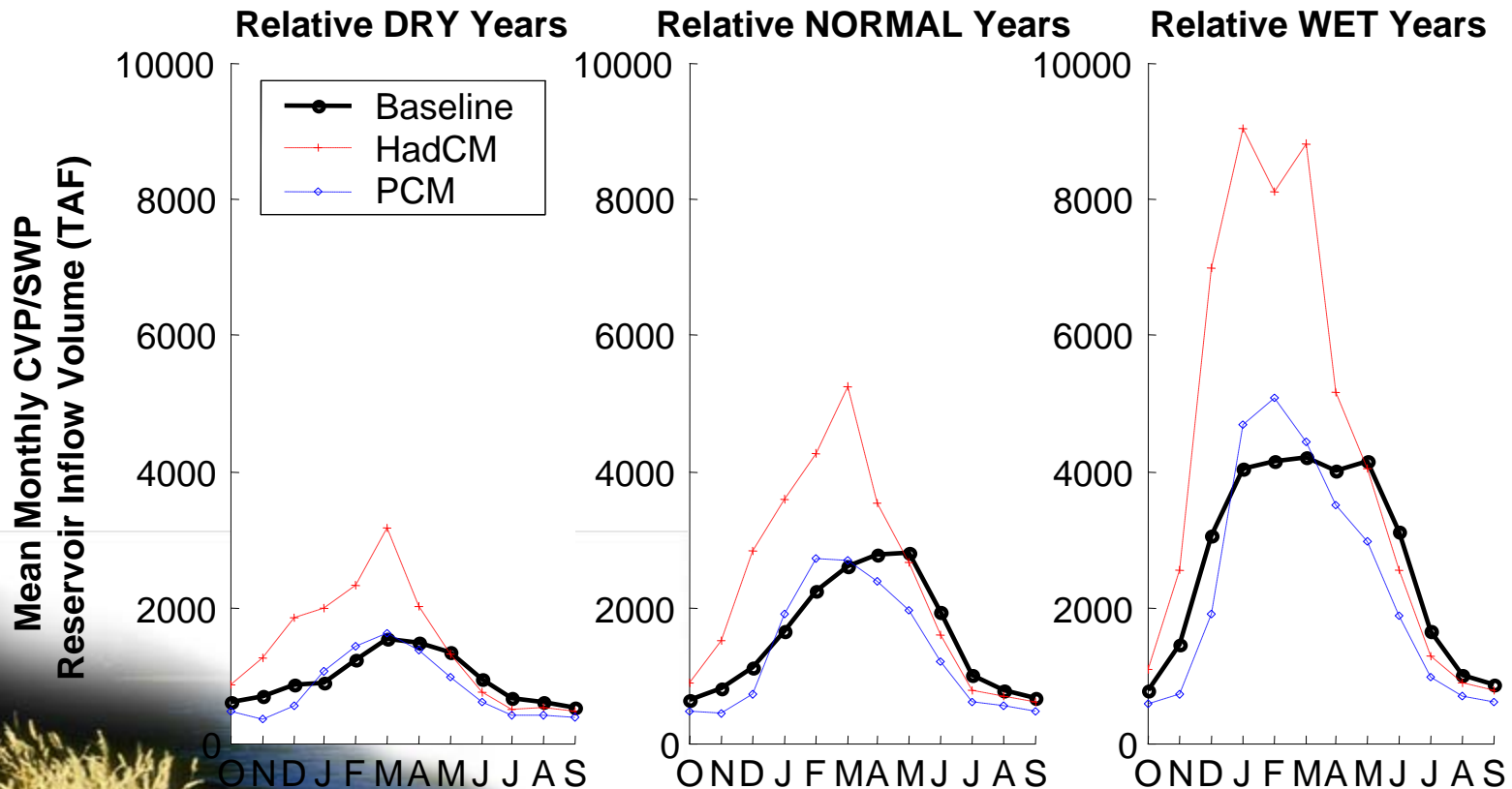
2) Store relevant model input and output data in HEC-DSS and MS-ACCESS

3) Write DMI's to link HEC-DSS with the model objects and GIS-based analysis toolbox.

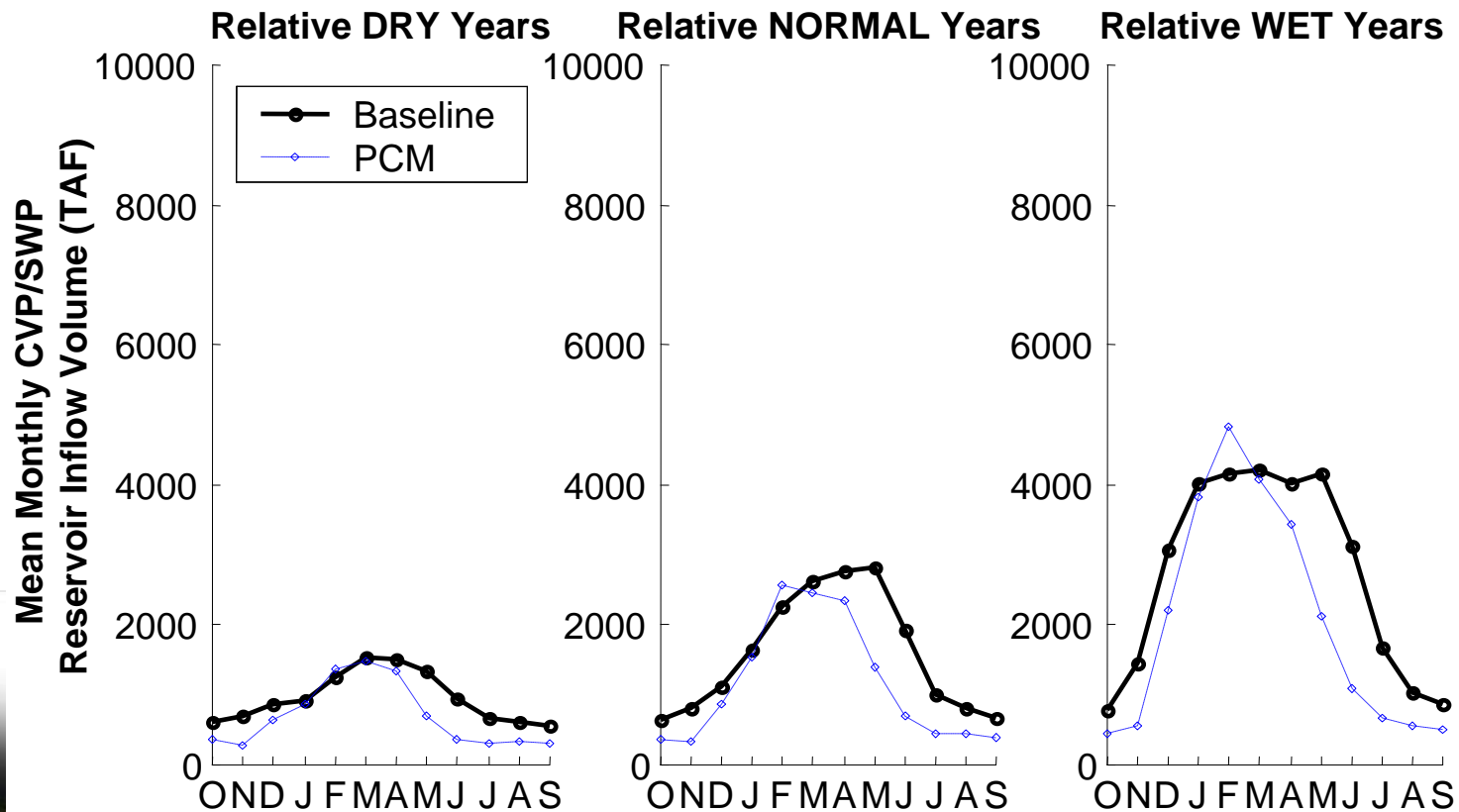
CLIMATE CHANGE IMPACTS ON CVP/SWP RESERVOIR INFLOW: 2025



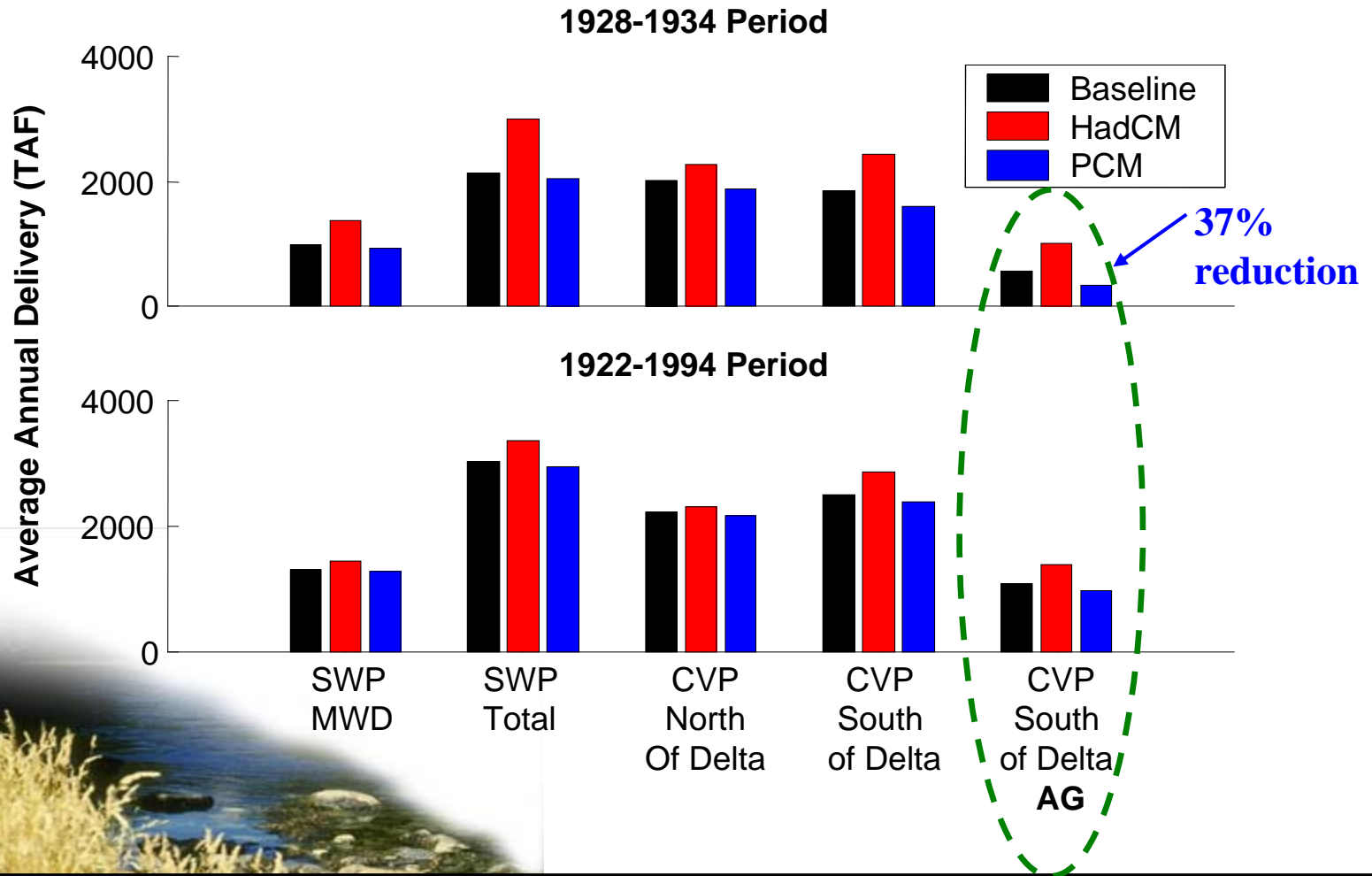
CLIMATE CHANGE IMPACTS ON CVP/SWP RESERVOIR INFLOW: 2065



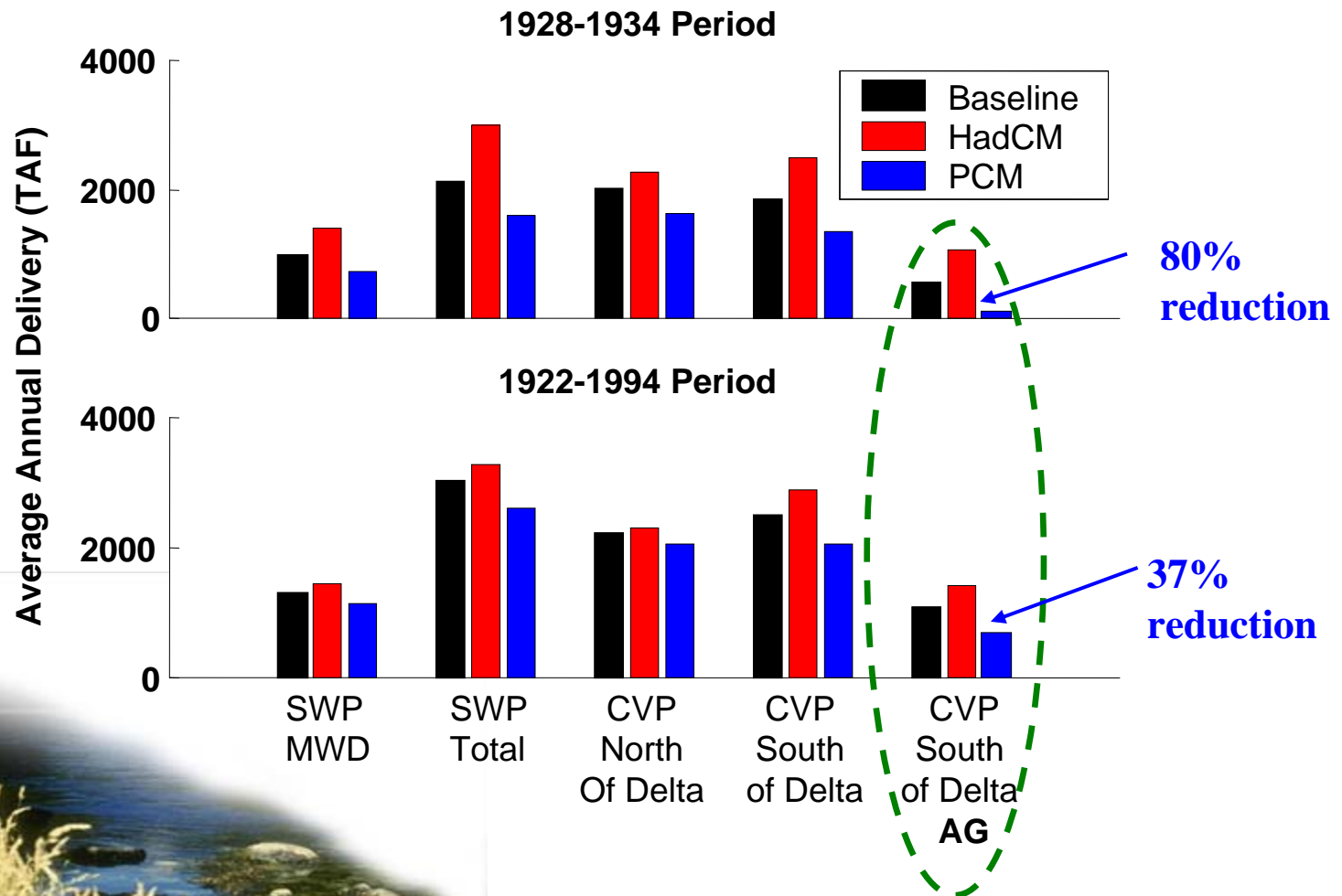
CLIMATE CHANGE IMPACTS ON CVP/SWP RESERVOIR INFLOW: 2090



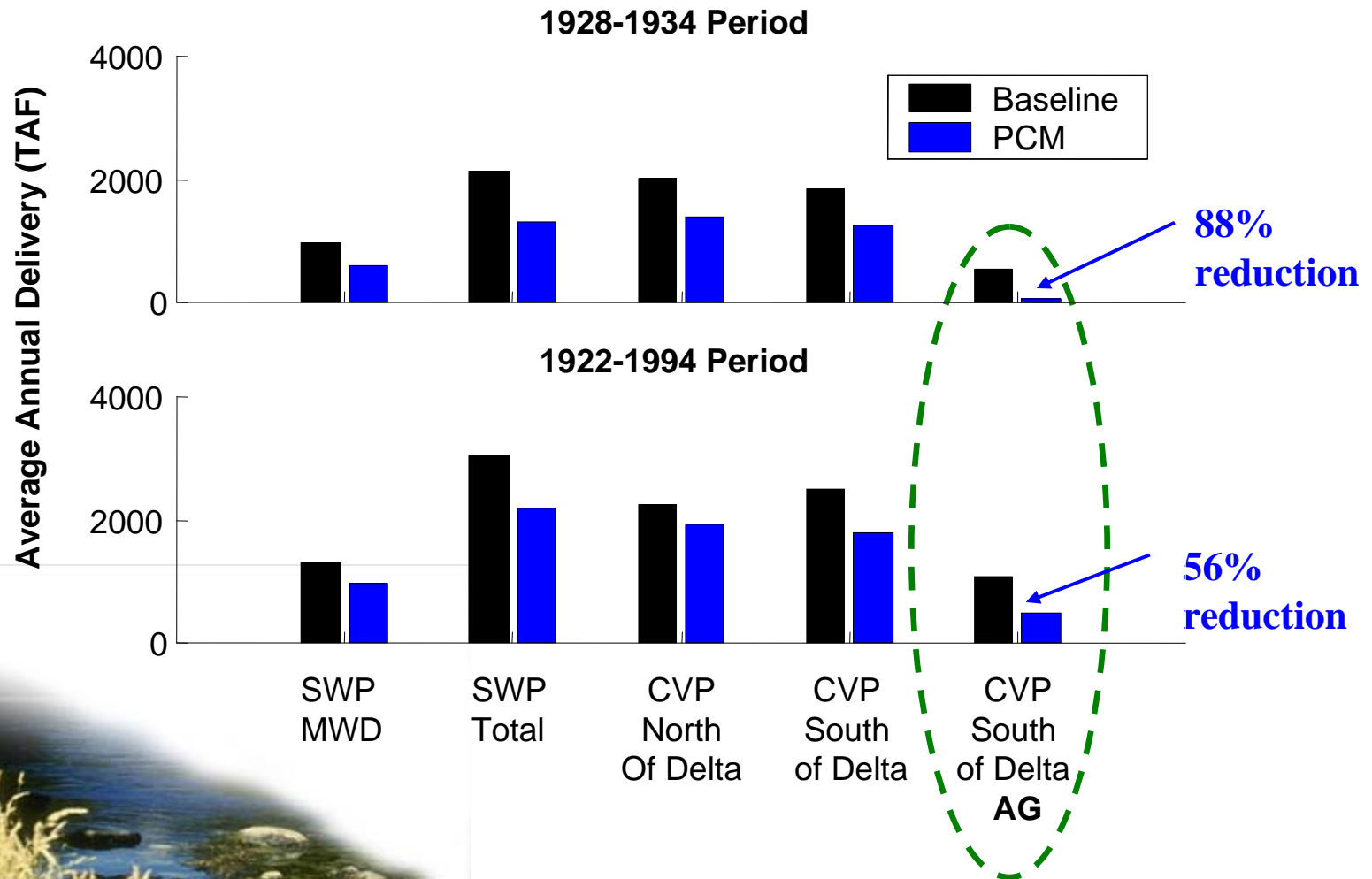
CLIMATE CHANGE IMPACTS ON CVP & SWP DELIVERIES: : 2025



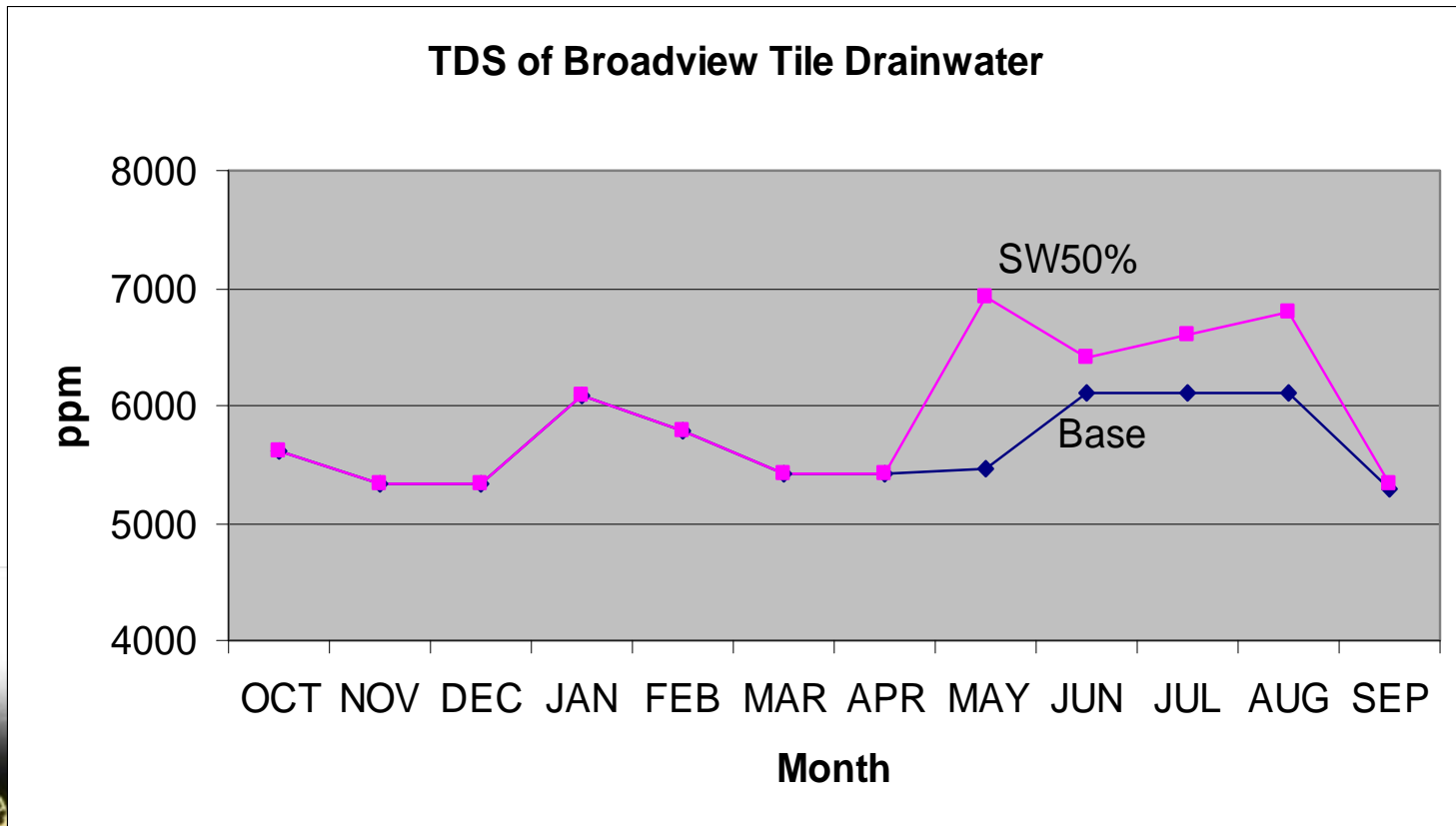
CLIMATE CHANGE IMPACTS ON CVP & SWP DELIVERIES: : 2065



CLIMATE CHANGE IMPACTS ON CVP & SWP DELIVERIES: 2090

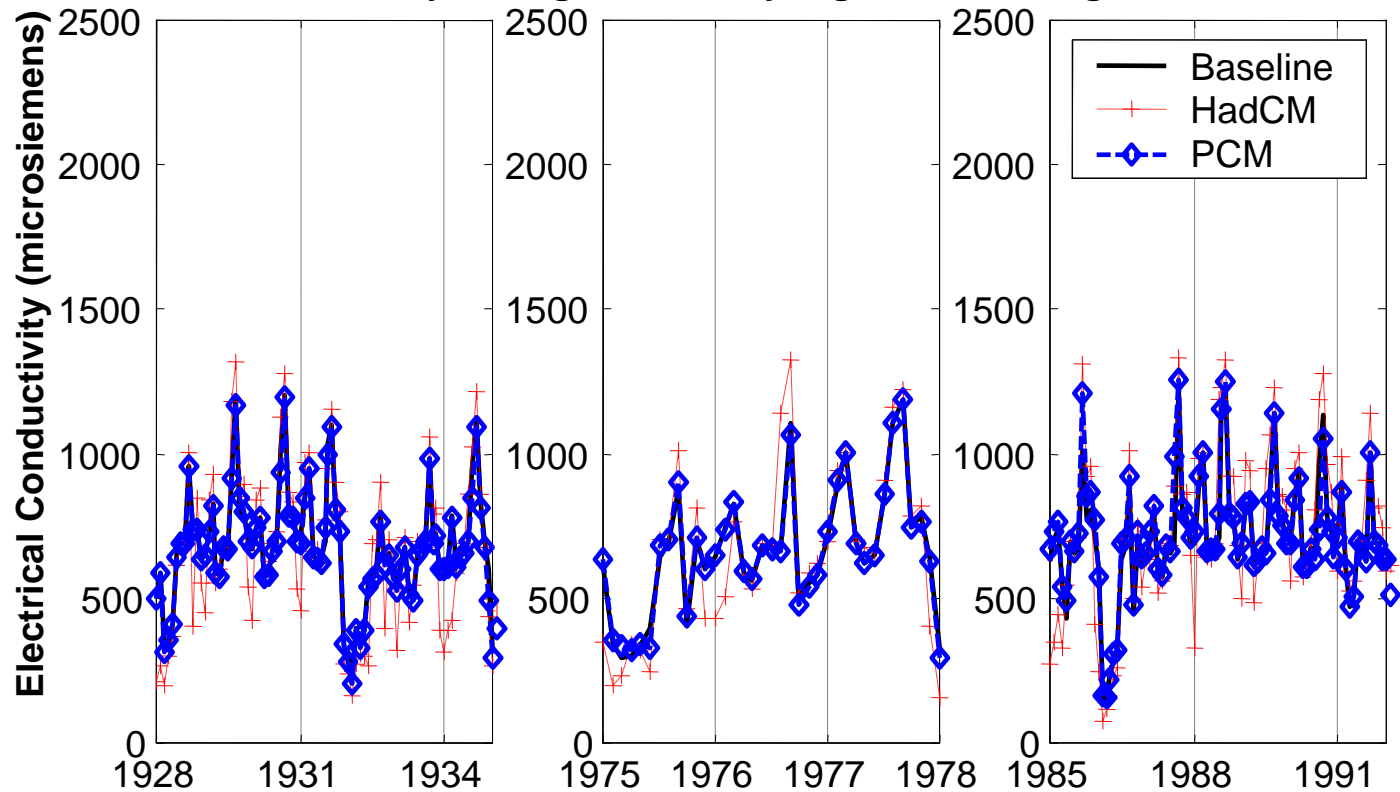


2025 APSIDE SIMULATION: DRAINWATER QUALITY IN BROADVIEW WD RESULTING FROM A 50% DECLINE IN SURFACE WATER AVAILABILITY



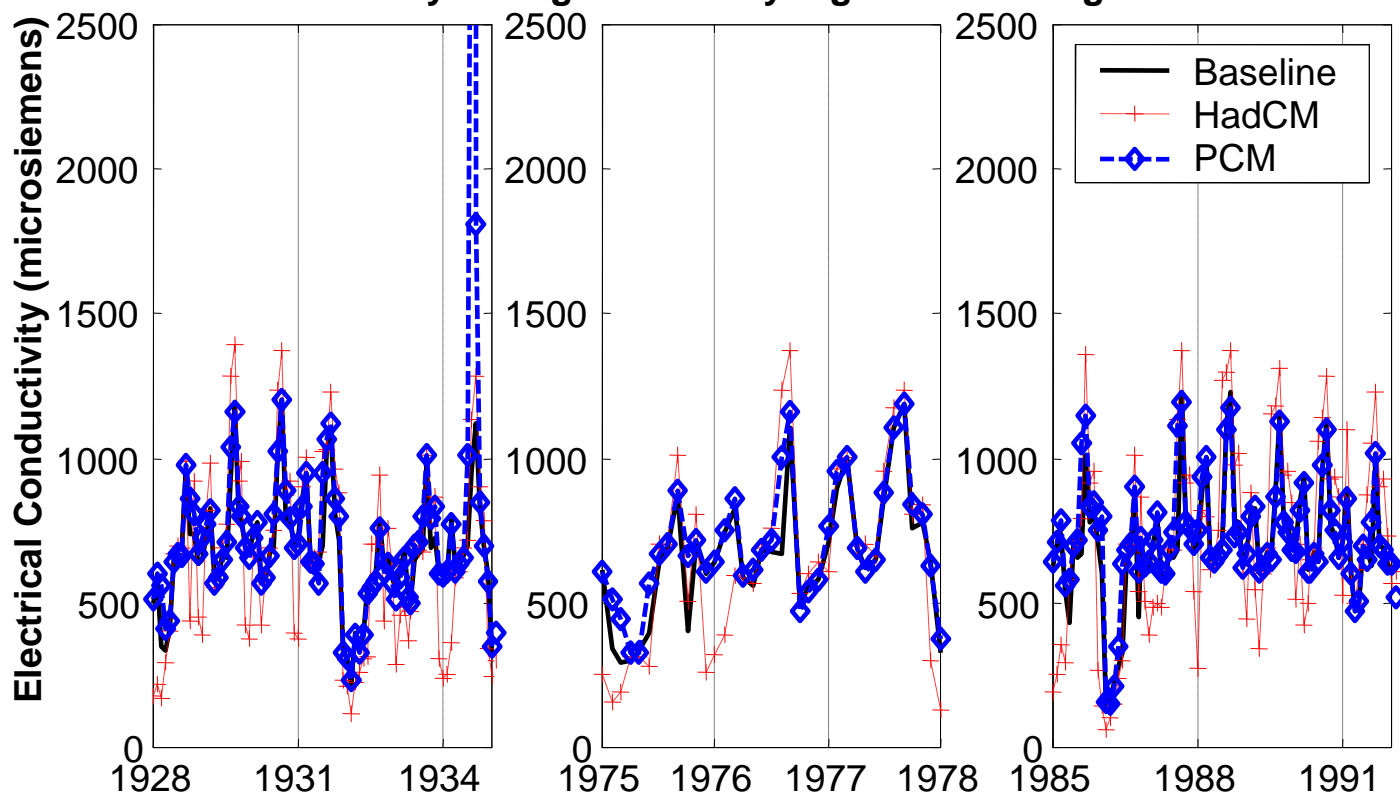
CLIMATE CHANGE IMPACTS ON VERNALIS SALINITY: 2025

Salinity during Historically Significant Drought Periods

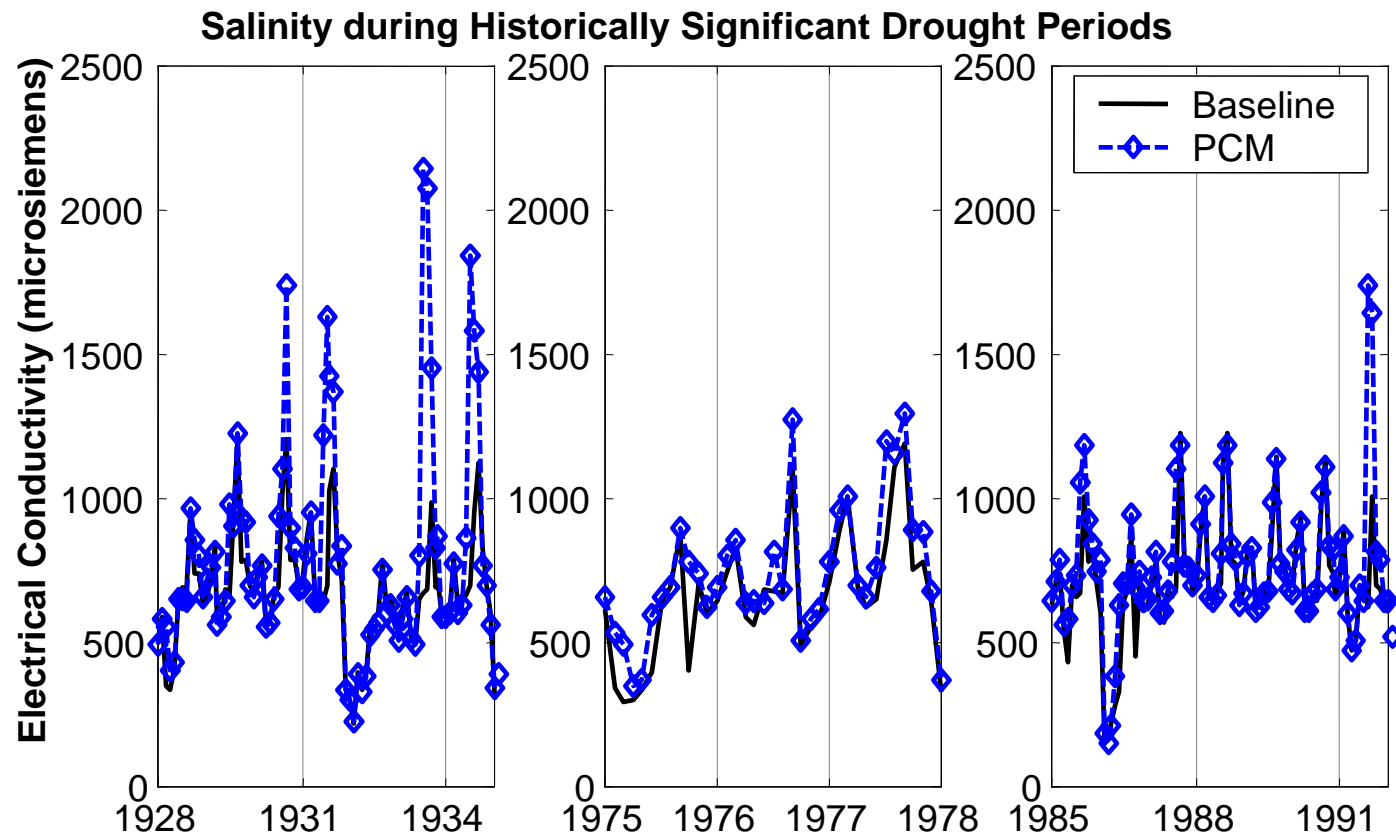


CLIMATE CHANGE IMPACTS ON VERNALIS SALINITY : 2065

Salinity during Historically Significant Drought Periods



CLIMATE CHANGE IMPACTS ON VERNALIS SALINITY : 2090



CONCLUSIONS

- A integrated modeling tool has been developed to simulate water resources, water quality, social and environmental consequences of climate change
- Public domain model integration tools evaluated lacked flexibility and were unable to work with variable time-step models
- Model integration was achieved with database centered approach using HEC-DSS and MS-ACCESS and scripts written in Java and J-Python
- The integrated modeling system suggests significant reductions in long-term water deliveries within the San Joaquin River Basin under climate change. These reductions in water deliveries lead to increased drainage salinity and water quality impacts in the San Joaquin River.